Research Program at the Lake States Forest Experiment Station

WOOD · WATER · FORAGE · WILDLIFE · RECREATION

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

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CONTENTS

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Lake States Forest Experiment Station

The northern forests vary tremendously—from the manmade shelterbelts of the Northern Great Plains, through the lake-dotted forests and bogs of Minnesota and northern Wisconsin, into the cool northern hardwoods of Michigan. This is the mid-continent area in which the Lake States Forest Experiment Station conducts research.

Lake States forests feed a complex of industries, protect the headwaters of three of the important river drainages of the North American Continent, provide a nearby playground for more than 25 percent of the Nation's population, and offer hunting grounds for an increasing number of people.

Under proper protection and development, these forests can be made to substantially increase their values in wood, water, wildlife, and recreation. But new knowledge must be made available. The key to this knowledge is research.

A BRIEF HISTORY

Lake States forests built mid-continent America. To the settlers, the trees that covered most of the region were an impediment to progress. But in less than a century the mighty pines were converted into stores, homes, and barns. The virgin hardwoods became furniture, floors, and paneling. The rich Lake States forests *did* serve a nation in the making.

But with the good came problems, too. Vast areas of logging slash fed the most devastating forest fires on record. Thousands of people lost their lives in holocausts and entire towns were reduced to ashes. The Peshtigo fire in Wisconsin occurred on the same day as the Great Chicago Fire *and it took more lives,* killing 1,500 people.

Fire changed much of the remaining forest, too. Brush and scrubby trees took over vast areas that once grew some of the Nation's finest forests. Watershed values were reduced, and in some areas rainfall washed away the fertile topsoil. Many northern forest areas were cleared for farming. Though the first crops were encouraging, most of the farms were later abandoned. The newly cleared fields were invaded by weeds and brush. Eventually, tremendous acreages reverted to County, State, and Federal ownership.

Thus, a host of problems suddenly needed answers in the Lake States. It was in this environment that the Forest Service, U.S. Department of Agriculture, established the Lake States Forest Experiment Station in 1923. Five scientists were assigned to the job. They were headquartered on the St. Paul Campus of the University of Minnesota.

Needless to say, these men had to concentrate their efforts upon the most pressing problems — cutting methods that favor seedlings of the right tree species, a system for determining forest fire danger, and sound methods for establishing and managing shelterbelts in the windswept Great Plains.

As basic principles were worked out, the Forest Service was asked to broaden and deepen the scope of research. It did this, gradually enlarging the Station staff to include such disciplines as economics, watershed management, genetics, pathology, entomology, engineering, recreation, and wildlife. Field headquarters and experimental forests,

F-503614
These men are the first three Directors of the Lake States Forest Experiment Station. Their service in that capacity has spanned more than 40 years. They are, from left, M. B. Dickerman, present Director; Raphael Zon, first Director; and E. L. Demmon, who replaced Zon and became the second Director. Mr. Zon, a pioneer in American forestry, went to work with Gifford Pinchot, America's first forester, at the turn of the century. Zon laid the foundations of an Experiment Station network that eventually spanned the Nation.

too, were established to put scientists near problem areas.

More recently, in response to a need for adequate facilities, modern laboratories have been constructed at strategic locations. These include the Northern Hardwood Laboratory, Marquette, Mich.; the Institute of Forest Genetics, Rhinelander, Wis.; the Northern Conifer Laboratory, Grand Rapids, Minn.; the Shelterbelt Laboratory, Bottineau, N. Dak.; and the Headquarters Laboratory, St. Paul, Minn.

The Headquarters Laboratory contains study space for scientists and a complex of specialized laboratories. It also has administrative space for the fiscal, editorial, personnel, and statistical services that serve the entire Station.

ORGANIZATION OF RESEARCH

The Station's research is now grouped into several important fields. Within each of these fields, a number of studies are set up to deal with specific problems. These studies presently number in the hundreds. Each is set up for a specified period of time, after which it is either terminated or extended, depending upon how the research has progressed.

A feature of the Station's research effort is a continuing program of cooperation with Universities, State forestry organizations, industries, and other interested groups. Thus, a wide variety of skills and facilities are brought to bear on complex problems.

In the following sections you will find a short description of research that is presently being undertaken. For more detailed information, you may write to the Station to obtain research publications.

Economics

FOREST RESOURCE INVESTIGATIONS

Foresters would have a difficult time if they tried to set up management plans without first understanding the extent and character of their forests. Also, industry could not afford to establish or expand a pulpmill or sawmill without first investigating the availability of raw materials. The forest resources must be measured and evaluated before these projects can be started. This is basic. Realizing the need for such information, the Congress in 1928 authorized periodic surveys of the forest resources of the United States. The first survey was started in Minnesota in 1933. It turned out to be a tremendous job.

The first winter was a difficult one. Temperatures plummeted to −56° F. in some areas and often the work was hampered by blinding snowstorms. The crews made east-west survey lines across the State's forests at intervals of 10 miles. They had to determine the extent and condition of the present timber supply; growth rates; use by industry; losses through fire, insects, and disease; and possible future timber needs.

In early 1937, after taking 125,000 sample plots in Minnesota, Wisconsin, and Michigan, the fieldwork of the first survey of Lake States forest resources was completed. Two more years of office work were required to turn the field data into statistics that could be published for use by land managers and forest industries.

Forests are composed of living, growing trees. Year by year, the face of the forest changes. These changes make new surveys necessary at intervals of about 10 years. Private industry and the State Conservation Departments were quick to realize the value of the survey. They offered to cooperate with manpower and funds so that more information could be derived from future surveys. As a result, the survey operation took on a more detailed character and the new information was made available for smaller areas.

In 1956, the Station's survey responsibility was enlarged to include the Central and Plains States, bringing the total area to be surveyed to 13 states — 100 million acres. The job would have been almost too difficult if the States and industries had not cooperated and if automatic data processing had not been developed.

Compilation of final statistics from the first Lake States survey took very nearly as long as the actual fieldwork. Today, computations that pre-

F-505907
Automatic data processing has proven to be an invaluable aid to the Lake States Station's Forest Survey staff. Here Tom Ginnaty, survey forester; Larry Liddiard, computer consultant; and Roland Buchman, Station statistician, inspect machine printout at the Data Processing Center on the campus of the University of Minnesota. Many members of the Station's technical staff have taken advanced training in statistics and computer programming so that they can use automatic data processing to the fullest extent.

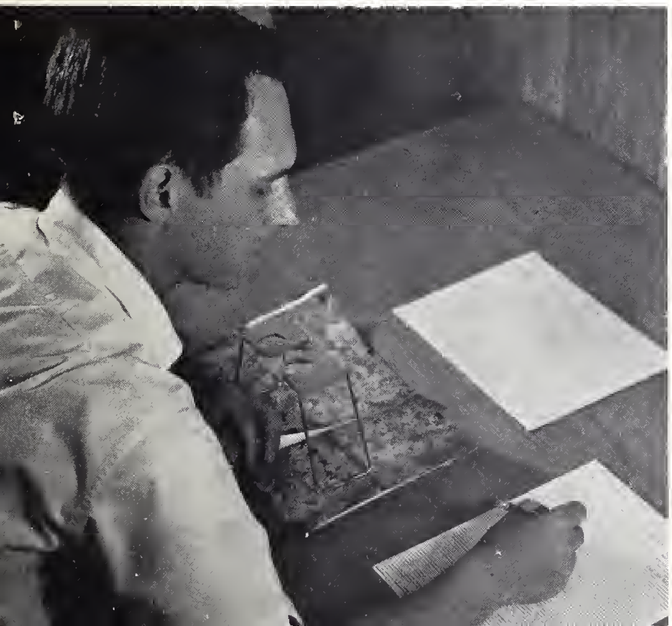
viously took a trained man months to complete are done by machines in *seconds* with more accuracy and detail and at less cost. The machine work is done in the data processing centers at the University of Minnesota.

The Station's forest inventory work has been underway for more than 30 years now. Minnesota has been surveyed three times; new work is in progress continually in several states. Certain new tasks have evolved as the need arose. Industries often ask specific questions that pertain to the survey statistics. Lake States staff members, working with industry, develop the answers. This sort of work has become increasingly important.

Another important job of the survey involves collecting and analyzing the production and demand for timber products. This effort results in annual surveys of pulpwood production and biennial surveys of veneer, poles and piling, mine timbers, and charcoal production. This information, when related to forest growth, has been instrumental in helping prospective industries decide where they should look for additional timber supplies.

This is the work of the forest survey. It is a challenging business that keeps a sizeable crew of men occupied. The demands of government agencies, as well as those of private industries, make this one of the most exacting of the Station's many responsibilities.

Paul DeBald, survey forester, records timber types and densities from stereo pairs of aerial photographs. Photo interpretation is the first step in the process of surveying the timber resources of a State. After this is done, foresters will take sample plots on the ground. Information derived from the photos and the sample plots will then be integrated and analyzed by automatic data processing machines to obtain final timber resource figures.



PRODUCTION AND MARKETING

How can the forest landowner make his land produce the most value during a given number of years? What are the existing markets for his timber, when the trees mature? Can new markets be located? What is the effect of changing ownership on production costs and the availability of timber? These are questions that the Station's production and marketing specialists are trying to answer. They are considering many new concepts that may help strengthen the role of forestry in today's competitive economy. The following are a few facts concerning this research.

How Can Forest Income Be Increased?

Every forest management project represents a bundle of investments. These investments include such things as planting, thinning, construction of roads, and protection costs.

If the harvest does not return the total investment plus a reasonable profit, the venture is a business failure. Forest stands in the Lake States are productive over relatively long growing periods, so financial decisions are important. Forest economics research can supply vital answers for the landowner. For instance, scientists know that

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New industries can make use of some of the small forest products that are available today. This new plant at Northome, Minn., employs about 12 men. They use cedar posts, cut in various ways, to produce fence sections for suburban landscaping.

trees grow more rapidly and reach merchantable size sooner if thinned to the proper level. But what does this mean in terms of dollars? Forest economics research shows the landowner when and how much to cut in order to get the greatest return on his investments. It also shows how to judge how much those investments should be for greatest percentage returns.

Another economic problem is timber supplies. Large timber supplies encourage new industries to settle in an area. But what happens if large ownerships are subdivided into small parcels and sold to a wide variety of interests? Many of the new owners may live long distances from the land, making it difficult for local loggers to contract timber sales. Others may prefer that no logging be done on their land. The result is a complicated checkerboard of ownership that may increase the costs of logging. These problems are present today, but they are not insurmountable. New concepts of land management and marketing could alter them. Research can find the answers.

Are Present Markets Fixed, or Can They Be Expanded?

Let us hope for two reasons that markets for timber products can be expanded. Northern Lake States counties need industries and the new forests need thinning and harvest cuttings.

The economy of many northern counties is based almost solely upon forest products, especially since mining has declined. Certain of these counties are considered to be "chronically depressed." The forest resource has recovered during the past several decades, and now these areas have a potential for expanded wood industries. Today, much of the material in the northern forests has reached merchantable size. It not only is available for use, much of it *should* be used so that the dense stands can be opened up for more growth. Otherwise, these young stands will stagnate.

Some difficulty lies in the fact that the forests have changed faster than their associated industries. How can sawmills that were set up to handle large saw logs economically handle small sawtimber of many different species? What will we do with the many thousands of acres of new forests that are far from any mill, transportation, and marketing facilities?

These are conditions that Station marketing specialists are studying. They are working with industry, pointing out some of the areas where the materials, transportation facilities, and markets are available or where they could be developed. They are also interested in possibilities for producing and marketing new products.

Protection

FOREST DISEASES

An apparently sound tree can actually be decaying faster than it is growing. While a thin layer of new growth is deposited on the outside each year, large areas of rot may be expanding inside.

All major tree species are susceptible to diseases — rots, rusts, diebacks, cankers, or wilts, to mention a few. These diseases destroy large volumes of timber, yet they are seldom spectacular killers. Though their life cycles are often fantastically complicated, fungi release so many millions of spores each year that even adverse conditions barely manage to hold them in check.

Diseases are so numerous that the scientists must limit their efforts to those fungi that are deemed most destructive. Generally speaking, the Station's disease research falls into three categories: diseases of northern conifers, northern hardwoods, and aspen.

Rusts Cause Much Loss in Northern Conifers

Several rusts commonly infect Lake States pines. Five species attack jack pine alone. Needle rusts attack red and other hard pines and spruce. White pine blister rust is presently receiving the most attention.

Blister rust is an imported disease. It originated in Asia, was carried to Europe, and finally arrived in the United States shortly after the beginning of this century. The damage became so widespread that Lake States foresters practically dropped eastern white pine from their list of useful species. But this tree is unusually valuable, both for its timber and its aesthetic qualities. So the Station has established studies to find ways to fight blister rust.

Eradication of ribes (plants that are members of the currant family) has been the only known effective preventive measure, but it is expensive. Removal of this alternate host is useful in protecting the remaining stands of white pine. Station pathologists have learned, however, that the blister rust is dependent for survival upon certain local weather conditions. They published this information, describing those areas where ribes eradication is not necessary. This research has helped to channel the eradication money into those areas where it will be most effective.

But the rust itself has not been stopped. The pathologists are studying several possibilities. They are trying to find rust resistant white pine strains, testing various antibiotic treatments, and studying mechanical methods, such as removal of cankers by pruning.

Root rots, such as *Fomes annosus,* are an important threat to conifer plantations. So far, losses have not been very serious in this region. However, as the plantations become older it is probable

F-504239
A bioassay project, in some respects, resembles an autopsy. This white pine tree is being dissected so that researchers can trace movements of an antibiotic previously applied to the tree to combat blister rust infection.

that root rot losses will increase and require substantial research effort.

Many Diseases Attack Northern Hardwoods

Northern hardwoods have unusually important disease problems. And, tree for tree, they represent the most valuable timber species in the Lake States. Present management recommends selective logging in northern hardwoods. This means that only a few scattered trees will be removed each time a stand is logged. Scars made on the remaining trees provide good entry courts for disease. So Station pathologists are not only concerned with natural problems — they also must deal with man-caused problems.

The research is conducted at the Station's Northern Hardwood Laboratory, Marquette, Mich. At this location pathologists are surrounded by industrial and public forests. Nearby is the Upper Peninsula Experimental Forest where they can conduct more detailed experiments. At present they are studying logging damage, sapstreak disease, maple dieback, stains, and heart rot.

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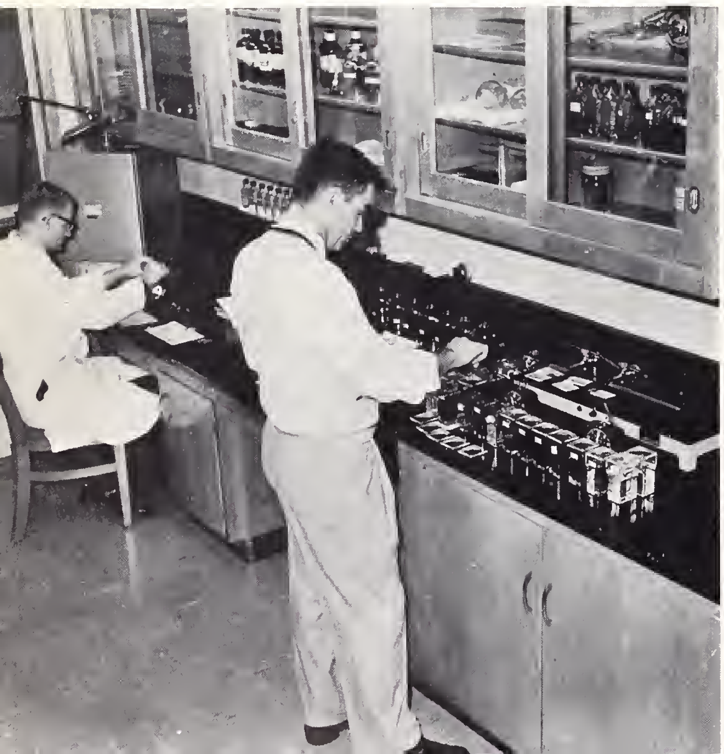
Forest disease research relies heavily upon laboratory studies. Much of the fungus activity takes place within individual cells of afflicted trees. This is a scene at the Northern Hardwood Laboratory, Marquette, Mich. Dr. Kenneth Kessler, left, slices extremely thin layers from a diseased piece of wood with a microtome. Richard Blank stains the sections for microscope study.



Aspen Studies Center on Hypoxylon Canker and Heart Rot

Hypoxylon canker is the most important killing disease of aspen. It attacks trees of all ages, causing cankers on the bole or limbs. Eventually the tree is girdled or snaps in two at the weakened spot.

Although the fungus has been identified, Station scientists have not yet been able to inoculate trees, except under conditions too artificial to resemble what might happen in nature. Before preventive measures can be found, pathologists must learn the entire life cycle of this fungus.

Heart rot and discolorations also merit attention. Heart rot causes the largest volume loss in aspen stands because it attacks the older and larger trees. To avoid total loss, foresters must cut most aspen stands before trees reach the larger, high-value sizes. Research should find a means for reducing this loss.

FOREST FIRE

Today, the forest fire problem is largely one of prevention and of understanding fuels. The past 30 years have been a period of regrowth in Lake States forests. Little logging was done, so fuels were limited. As our forests mature again, however, the trend is toward more cutting. This creates more fuel, increasing fire hazard. Thus, as our forests mature, the potential for major fire losses increases.

The foliage of coniferous trees is fairly flammable during certain seasons, but the real culprit is material on the ground. Branches, leaves, and needles that are left after logging quickly dry out to a point where they would make fine fuel for a bonfire. When you consider that this material is sometimes present throughout areas of several hundred acres, you can imagine the tremendous fire potential that exists in these places.

Coniferous plantations, too, offer dangerous fuel combinations at certain times of the year. The litter of dry needles and twigs covering the ground is a good starting point. Dead branches on the lower boles of the trees are a good medium through which a fire can climb. And the solid sea of unbroken crowns, once heated, provides fuel for a rolling, killing blaze.

Fire Shows Promise as Forestry Tool

The Station has been involved in fire research for 40 years. Early efforts were directed toward developing a system of rating forest fire danger, classifying fuel types, and maintaining statistical summaries of the number of fires, area burned, and damages.

Today, fire research scientists are learning that fire has many beneficial results when applied under a predetermined set of conditions and when properly controlled. They are intentionally starting fires during favorable weather to attain specified land management objectives. These prescribed fires can be used to remove large concentrations of fuel that might otherwise become ignited and destroy the forest during periods of high fire danger. This is called "hazard reduction." Prescribed fire may also be used to control undesirable tree or brush species that are competing with the more desirable trees or to remove some of the dead, matted surface fuel that discourages germination of tree seeds when they fall to the ground. These are silvicultural uses of prescribed burning. And prescribed fire can be applied to maintain or create wildlife food and cover.

More experience is needed to perfect the use of prescribed fire in forest management. As this experience is gained, fire will be used more and more often as a land management tool because it will do a specific job at a reasonable cost.

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These pictures represent two entirely different types of fuel situations common in today's coniferous forests. At top, a thinning operation has left a concentration of slash material on the ground that will remain a dangerous fire hazard for several years. Bottom photo shows a plantation with a thick layer of dry needles on the forest floor, dry twigs on the boles, and a dense canopy of needles in the crowns. Either situation could produce a disastrous fire if the fuels were ignited during dangerous burning periods.

FOREST INSECTS

The Lake States have been the scene of tremendous timber losses through insect epidemics. Insects always take a toll in the forest, but their damage varies in character and intensity. Some weaken trees, slowing up growth. Others deform trees, decreasing their value. And still another group can be classed as tree killers, although the ways that they accomplish the job are quite varied.

Insect depredations occur throughout the entire life of a forest. As a matter of fact, insects

F-500772
The European pine shoot moth can cause serious growth losses in Lake States red pine if it is not controlled. The crooked stem above the hat is an example of the damage. This insect kills terminal buds, rather than the entire tree. Crooking or forking of the main stem often results, reducing the value of the tree.

sometimes destroy a forest before it is even born. Those that feed on certain tree seeds occasionally destroy 75 percent of the annual seed crop.

Most problem insects have been here much longer than man. Their activities are often cyclic. Although they can reproduce at very rapid rates, natural conditions normally keep their populations low.

Occasional insect "population explosions" cause important damage to the forest. When conditions favor the reproduction and survival of a certain insect, the population could very easily increase a hundredfold. Station entomologists are trying to develop ways to predict unusual population trends and control them when they occur.

Another situation that sometimes encourages population buildups is a forest plantation or shelterbelt. Forests usually tend to be mixtures of tree species. Wherever man plants a block or strip of a single species, he is offering insects a perfect food and cover situation. Often the population will build up accordingly. This problem, too, can be averted through selection of the proper tree species and the use of biological and cultural controls that are described in the following paragraphs.

Spraying of Insecticides — A Temorary Control

A number of insecticides have been used to control insect populations. But insecticides are not the final answer. They are expensive and occasionally may create undesirable side effects. Rarely will one spraying prove effective for more than one or two seasons.

Biological Controls Offer More Permanent Solutions

Insects have natural enemies. They may be predatory or parasitic animals, bacteria, fungi, or viruses. In theory, the most effective of these enemies could be reared in laboratories and released during periods when the host insect is at high population levels.

These biological controls are normally inexpensive. Once released, they *seek out* the troublesome insect — and they continue to do so.

The field of biological control is a relatively new one. Station entomologists must study it thoroughly before trying it out on a large scale. It could eventually replace insecticides as a means for combating many insects.

Cultural Controls Are Useful Tools

Forest plantations are artificial situations that lend themselves to high insect populations. However, certain practices can be introduced to offset the situation. Station entomologists start out by studying the life cycle of an insect before trying to develop control measures. Very often they discover a weak spot — a period when the insect is vulnerable. Control measures are aimed at this weak spot.

A good example of such research is a cultural practice that is now used to control European pine shoot moth populations. This insect found red pine plantations to be excellent habitat. It caused considerable trouble, killing back the new growth of young trees. Station entomologists learned, however, that overwintering larvae cannot stand low winter temperatures. Those that survive are in-

F-504463
The Station's forest insect staff has constructed semipermanent scaffolding around several trees in northern Minnesota. These structures allow entomologists to study insect activities high off the ground without seriously disturbing the natural environment.

sulated in the tips of branches below snow level. If these branches are pruned off, the larvae must overwinter above the snowline. Most will then be killed.

The planting site, too, sometimes has a strong influence upon insect populations. Certain tree species resist attack if they are planted on a site where they can grow vigorously.

But An Early Warning System Is Needed

Regardless of what control systems he uses, the forester must know when to expect bumper insect populations. Station entomologists are developing sampling methods that may provide the answer. They find that dangerous population trends are often present long before the trees show damage. Insect counts on small samples of trees may be useful in estimating populations throughout plantations. However, each insect species must be treated separately. A relatively large population of one species may not be dangerous, while half as many of another could mean impending disaster.

These are the types of problems that the Experiment Station's forest entomologists are facing. They have made good progress during the past few years. They are working toward even better results in the future.

Recreation and Wildlife

FOREST RECREATION

Forest recreation is becoming an increasingly important use of America's timberlands. The Nation's population has doubled during the first 60 years of this century, and most people have more free time and money than before. This, coupled with more education, changing tastes, widespread ownership of automobiles, and modern highways, has set the stage for more and more people to seek the forest for recreation.

The impact has been tremendous — especially in the Lake States where forests are within a day's drive of 25 percent of the Nation's population. The demand for forest recreation has grown faster than facilities. Also, recreation interests vary widely. Some people seek wilderness, while others prefer an improved campground. Canoeing, speedboating, swimming, fishing, hunting, hiking, horseback riding, skiing, and auto sightseeing are just a few of the things that people can do. Some of these interests conflict and require management decisions to avoid trouble. The use of the forest

F-498975
Solitude — that is the environment outdoor enthusiasts seek on a canoe trip. But if most canoeists use the same area, they may actually have to wait in line at the portages. This problem has already occurred at some locations, yet other spots are visited by only a few parties during an entire season. Before we try to encourage a more even spread of use, we must understand the reasons for the present concentrations.

F-504531
Family camping has become one of the fastest growing uses of the National Forests. But we know little about how satisfied people are with the facilities that they find in the campgrounds. What are they looking for? What do they do? What would they like to do? How long will they stay? Will they come back? These questions must be answered and analyzed before the land manager can be sure he is on the right track when he installs new facilities.

itself is sometimes spotty. Station recreation specialists have found, for instance, that the use of the "Canoe Country" in northern Minnesota is concentrated in a small part of the total available area.

Management systems have lagged behind. In many cases, improvements are based upon guesses, rather than sound data — simply because the information is not available. By developing and publishing such information, recreation research can do much to help administrators and businessmen satisfy the needs of the public and avoid inefficient use of funds.

Use Problems Emphasized

The Station's recreation research has centered around National Forest use. Other public and private recreation problems will be considered in the future. Station scientists are trying to determine who the recreation seekers are and what types of forest settings they prefer. What facilities do they want? How far will they travel? How long will they stay? These are some of the questions that must be answered if opportunities for high-quality forest recreation are to be available in the future. Knowing more about what kind of people choose the different types of recreation helps in estimating future demands or desires. Knowing more about preferred sites and travel patterns helps landowners choose locations for new developments. Knowledge about attitudes on facilities aids in planning these developments. Information on users' opinions of crowding can help land managers select controls that will benefit everybody. Not all visitors want the same thing; the "ideal" recreational plan may be something like a jigsaw puzzle. Research can identify the pieces and help show how they fit together.

WILDLIFE HABITAT

Most of the Station's wildlife habitat research concerns two species — white-tailed deer and ruffed grouse. However, land management practices that benefit these species are, with a few exceptions, good for most other forest animals.

The white-tailed deer is one of the many native animals whose survival depends upon the food and cover available within the forest. These animals, in turn, can influence the quality of forest growth because they feed directly upon tree reproduction. A balance must be reached that will allow both the animals and the other forest values to thrive. Wildlife habitat research will help the forest manager to establish and maintain this balance.

Forest wildlife usually prospers in an area with a wide variety of forest cover and numerous openings. For example, during the period of heavy cutting, deer populations increased tremendously over what they were during virgin forest conditions. Now natural growth, along with protection and management, has permitted the forest to "grow up." This is reducing the game population's food supply. Under these circumstances, pressures build up on both the forest and the game. Management practices that will benefit game without disrupting other forest values are under investigation. These are the procedures that Lakes States Station wildlife habitat specialists are seeking.

We must know more about the browse production of different forest stands before we can intelligently coordinate wildlife needs with intensive forest management. Studies are presently underway on several National Forests to determine the browse production potential of major forest types.

Openings fulfill a variety of wildlife needs. They provide food, increase forest edge, create variation in temperature and moisture conditions, and serve as wildlife gathering places. Under natural conditions, openings are created by windfall and fire. In the younger, managed forests of today, openings are often rare and must be developed as needed.

Some openings are more or less permanent. They may be frost pockets that do not favor tree growth, or they may be abandoned logging camps or farms that are kept open by heavy sod. Openings that are created by logging or fire are often temporary. They support brush, berries, and herbs for a short time until trees again take over the site. Experiments are underway in cooperation with the University of Wisconsin to classify the different types of openings. Later work will involve methods for establishing those that are beneficial to wildlife.

There can be no doubt that wildlife is important. Wild animals are a valuable resource that should be managed for aesthetic values, for sport, and for food. However, when the population is larger than its food supply, the forest is sometimes injured. Lake States Station wildlife habitat specialists are searching for ways to reconcile wildlife needs with other forest values through the manipulation of food and cover. If this can be done, all users of the forest will benefit.

Water

WATERSHED MANAGEMENT

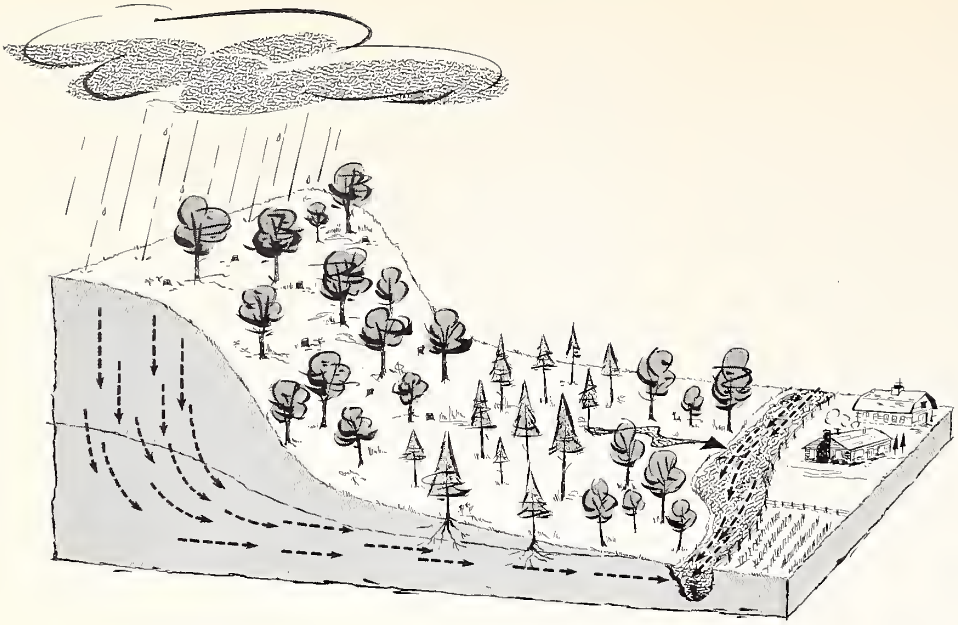
Water is one of the most important of our renewable resources. Forest lands are underground reservoirs. But how efficient are they? How well do they catch and hold snowmelt and spring rains, then ration the water to river drainages and underground flowages? These are mysteries that need further research.

The forests of the Lakes States contribute to three major Continental drainages. These huge areas of lakes and woodlands *appear* to have more than enough water to fill all future needs, but actually they do not. Annual precipitation in the Lake States is less than the National average. The annual runoff, too, is somewhat less than the National average.

At the same time, competition for water is increasing. Each type of user needs more than ever before. We must somehow help the forests to conserve the water that they have. The Experiment Station has developed a substantial research program to uncover new information concerning the region's watershed management problems. The work falls into three major areas: ground water, erosion, and northern bogs.

How Do Soils Affect Ground Water Movement?

Most of the region's water supply is in the soil. It slowly percolates through underground soils until it reaches streams or erupts in small, cold springs. But we do not know what routes it takes underground and how fast it travels through different soils. Furthermore, we are not sure how different types of ground cover affect the penetration of surface water. Once these and other problems are better understood, we should be able to coordinate forest management practices with watershed ob-



What forest management practices on the slopes of a watershed will encourage the greatest amount of precipitation to penetrate into the soil? Free water that flows down the surface of the hillside is mostly lost. Water that seeps into the soil will filter down to the lower areas throughout the year, serving the needs of the farms, forests, and streams in the valley below.

jectives and actually help the soil absorb more water than it now does. This could prove quite important in future years, as our water needs grow.

Most of the Experiment Station's ground water research is conducted on the Udell Experimental Forest in Lower Michigan. A network of recording wells and weather stations has been installed there to help scientists determine what percentage of the precipitation is absorbed into the ground and how water moves through the soil.

The watershed scientists plan to establish a number of different forest management practices on the Udell to determine their effect upon the ground water regime. This work has already uncovered new concepts of ground water activity.

Can Flooding and Erosion Be Reduced?

If we can control the surface runoff of water, we could reduce seasonal flooding and erosion. Station scientists know that runoff cannot be stopped completely, but it can be channeled and slowed to the point where most of its damage would be minor.

The Station, in cooperation with the State of Wisconsin, has established an experimental forest in the Coulee area of southwestern Wisconsin. This is an area of fine farmlands and rolling wooded hills. For some reason it was bypassed by the glaciers that rebuilt the surface soils and topography of the Lake States. As a result, Coulee soils are composed of a fine, wind-deposited material called loess. Early farming practices in the Coulee area increased the runoff of surface water, causing severe damage to the light soils on the hillsides.

This problem is now under study on the Coulee Experimental Forest. Flumes and weirs have been installed so that runoff from different cover types can be channeled through measuring devices. The objective of this work is to determine what combinations of cover types will best protect the loess soils.

Other erosion is occurring along streambanks in many Lake States localities. Spring floods do much

F-504138

This is typical of the gullies that have been eroded into the hillsides of the Coulee area in southwestern Wisconsin and Southeastern Minnesota. For a full appreciation of the size, notice the man standing in the bottom of the gulley (arrow). Fine, wind-deposited soils make this area very susceptible to serious erosion.

of the damage in these areas. The riverbanks can be protected if rock fill is deposited along the waterline and combinations of vegetation are established on the upper banks. But this remedy is expensive. The Station's watershed staff is experimenting with less costly stabilizers, including several petroleum and latex products, to see if they will hold the soil in place while vegetation is becoming established. The scientists are also testing different types of vegetation to determine which are most capable of providing quick cover on steep, eroding banks.

What Happens to Water in Bogs?

The third major effort deals with a very large area that previously has received little attention — the 11 million acres of bogs in the northern counties of Minnesota, Wisconsin, and Upper Michigan. Practically nothing is known about the watershed characteristics of these bogs.

Early studies have shown that the different peats vary considerably in density, composition, and water-conducting characteristics. These properties will be further investigated.

Bog vegetation, too, is something of a mystery. How much water does it remove from the peats? Does it offset this drain by reducing surface evaporation? Do the root systems affect the conductivity of peat soils?

These are questions that Experiment Station watershed scientists are studying. They are using the Marcell Experimental Forest in northern Minnesota as a testing ground. The Forest has bog areas that are typical of those that cover many northern areas in the Lake States. Five of these bogs have been calibrated to determine their role in the water regime of their localities. Eventually this information will help forest managers manage their bogs for best production of all forest resources.

Timber

PLANTATIONS, SHELTERBELTS, AND SITES

Plantations and shelterbelts play an important role in the Lake States and the Northern Great Plains. And before a plantation or a shelterbelt is established, the forester must try to select the best species for the site. Site requirements are especially important in these plantings because both are artificial situations. Furthermore, they require the largest per-acre forest management investments in the region. The seed must be collected in the field and germinated in specially treated nursery soils. When the young trees are large enough they are transported to the planting site and planted according to a prearranged plan. These operations alone represent considerable expense. As the trees grow the plantations must be thinned, the shelterbelts must be cultivated, and both must be protected. This involves more expense. Think of the waste that is involved if the trees are not well suited to their environment.

F-500549

A plantation cannot produce maximum income unless it is properly managed and protected. This experimental planting on the Pike Bay Experimental Forest in northern Minnesota began producing merchantable pulpwood at an early age. It has since yielded very well in periodic thinnings and will continue to do so until the final harvest is made. Much of the success of this plantation can be attributed to good management.

F-493116

Thousands of miles of shelterbelts have been planted in the Northern Great Plains. More will be planted in the future. These long rows and blocks of trees and shrubs protect the soil from erosion and excessive moisture loss, shelter crops and farmsteads, provide food and cover for wildlife, and beautify the landscape. The Lake States Station conducts research to provide new information concerning the establishment, management, and protection of shelterbelts.

Plantations, shelterbelts, and species site requirements are all considered in Lake States Station research.

Pine Resources Depend Upon Plantations

Three million acres of plantations comprise nearly three-fourths of the pine acreage in the Lake States. These and future plantings, properly managed, can eventually supply most of the region's pine timber needs. Plantations may be managed for 100 years or more before they are harvested. During this period many important decisions must be made concerning their establishment, culture, and protection. Research can help the land manager make the *right* decisions.

The landowner cannot rely upon the experience of others because few of the existing plantations have had time to reach maturity. But information, such as growth rates, projected earnings, and best planting and thinning practices, is being made available through research. This is proving to be a valuable aid to the man who must make management decisions.

Past work has helped the landowner select planting stock that is most suitable for his purposes. Station scientists have published information recommending seed from local sources because trees from other regions sometimes react unfavorably to local conditions, even though they are the right species. Also, the age of nursery stock is important. Two-year-old seedlings do well on some sites. But in areas where weed competition or drought is a problem, 3-year-old stock that has been transplanted in the nursery is more likely to survive.

Shelterbelts Provide Multiple Benefits

Shelterbelts are long rows or blocks of trees that protect crops and farmsteads from drying winds, provide protection for wildlife, and add aesthetic beauty and relief to the Great Plains. Shelterbelts were first planted on a large scale in the early thirties.

Through the years the Experiment Station has supplied information concerning the establishment, management, and protection of shelterbelts. A considerable store of information has been uncovered during the intervening years, but the job is far from completed.

Trees are at a disadvantage in the Plains because the climate is better suited for growing grasses, weeds, and crops. However, certain tree species and strains within species can produce sturdy shelterbelts. Station scientists have collected tree seed from many parts of the world to see which are best. These are tried out in experimental plantings.

Cultivation is important, too. Weeds and grasses must be held in check until the trees are large enough to hold their own. This could be accomplished through mechanical cultivation or perhaps with herbicides, But it is expensive, so the landowner wants to know how much and how often he should cultivate.

Rooting must also be considered. In certain areas a tree must send roots deep quickly or it will die during the dry summer months. Also, trees that grow deep rooting systems are preferable to those that rely upon shallow lateral roots. The latter steal water from nearby crops during the late summer.

Shelterbelt design is another field of study. Belts with different structures affect windflow in varying ways. The ideal belt is one that will slow the drive of surface winds for a long distance without creating local points of turbulence.

In recent years the research has become more complicated. Scientists wish to delve deeper into

the many factors that affect tree survival and growth. Much of the work must be done in a laboratory. This is one of the reasons why the Station constructed the Shelterbelt Laboratory at Bottineau, N. Dak., on the campus of the North Dakota School of Forestry.

Forest Sites Influence Species Selection

Tree survival and growth often depends upon the selection of the right species for the site. This is not often a problem in a natural forest because the seed comes from trees that have proven their compatibility with the site. But when a forester wishes to introduce a plant he must be careful.

Station scientists have progressed well in this work during the past 30 years. They published information describing a number of different plantation sites and suggested tree species that would do well in these locations. Furthermore, they helped land managers decide what nursery stock age classes would be most suitable.

But foresters are planting areas that previously would not have been considered worthwhile. Some sites that are used today have deficiencies that were not considered in the original guidelines. Also, the earlier work suggested several species for a given site. A better understanding of site requirements might help us select the *best* tree for that site.

Present research is directed toward a refinement of what we already know and the discovery of new facts. It involves analysis of tree foliage to determine what amounts of various minerals are present. The next step is a soil analysis to make sure that these minerals are present in sufficient amounts. In some cases soil fertilization may be used to condition sites for best tree growth.

SILVICULTURE OF LAKE STATES SPECIES

The first major product that Lake States forests provided for the white man was timber. And timber, so far, has proven to be the most important income-producing member of the forest resource family. Thus it was necessary from the very beginning, that the Station conduct studies in silviculture—the art of producing and tending a forest.

The research is centered around three major timber types: northern conifers, northern hardwoods, and mixed hardwoods. Each of these presents complicated management problems.

Conifer Acreage is Small

Conifers once covered 25 million acres in the Lake States. They were mostly removed by 1910. Their slash fed a series of devastating fires that killed reproduction and laid the land bare. In the early thirties large-scale planting operations were begun. The planting has been continued right up to this time, yet only about 3 million acres have been returned to coniferous forest growth.

Now the problem is becoming more difficult. Few open planting sites remain, and much of the original conifer acreage has reverted to brush and undesirable trees. With its present cover, this land is worth practically nothing. It will produce little timber and has practically no scenic value.

Somehow we must convert these vast acreages to thriving forest. The problem is one of economics. How can the forester make the conversion without bankrupting his timber enterprise? Should he use bulldozers, huge slashers, herbicides or prescribed burning to remove the unwanted cover?

All four procedures have been studied. The first two are expensive and can be used only on

F-506161

The Pike Bay Experimental Forest in northern Minnesota is a 3,600-acre outdoor laboratory where Experiment Station scientists study type conversion practices. This scene is a good example of "before and after." On the left is a stand of poor quality hardwoods that took over the entire area after the original coniferous cover was logged. On the right is a conifer plantation that was established after the hardwood cover was removed in a conversion experiment.

the best sites. The latter two need more research. Other methods will be investigated.

Northern Hardwoods Must Be Managed Differently

Northern hardwoods pose an entirely different set of problems in northern Wisconsin and Michigan's Upper Peninsula. Except for yellow birch, the difficulties are not centered around the establishment of the new forest. Northern hardwoods reproduce well in their own shade. When the old trees are removed, young ones stand ready to take their places. The problems lie in thinning and harvesting procedures.

The northern hardwood forest, composed mostly of maple, birch, and beech, tends to be dense. The trees are patient. They can remain small for 20 years or more, waiting for a tree to fall, creating a sunlit opening. When they finally receive the light of the sun they shoot up and take their places among the larger trees.

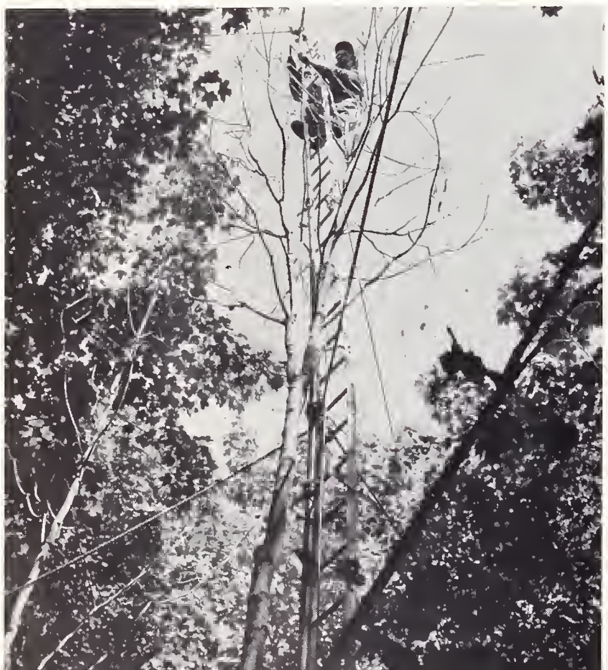
To make his northern hardwood forest productive, the forester must keep the trees growing. He can't afford to wait until natural openings allow occasional trees to grow. He must thin the forest so that it will grow uniformly, slowly developing trees of all ages. The big question is how much should he thin? If he takes too many trees out, the sun is likely to scald the bark of those that remain, possibly causing defects. Or dormant buds on the lower stems may be encouraged to sprout, growing limbs that will degrade future logs.

Thinning, itself, is an expensive operation. Until recently there was practically no market for materials that were smaller than sawlog size. Now a certain amount can be sold as pulpwood, but the market is small. Research must help the forester decide how best to thin his hardwoods, from the standpoints of quality and economy.

Culls, large trees that have no timber value, are a problem in the management of all hardwoods. They stand for long periods of time — maple, for instance, is quite capable of living more than 300 years. The first loggers left many culls in the woods. They still stand and will continue to do so, taking up large areas of prime forest site. If the land is to produce its maximum of valuable timber, these trees must be removed or at least killed. Cull removal, using present methods, is expensive. Research may eventually develop more efficient ways to do the job.

F-504616

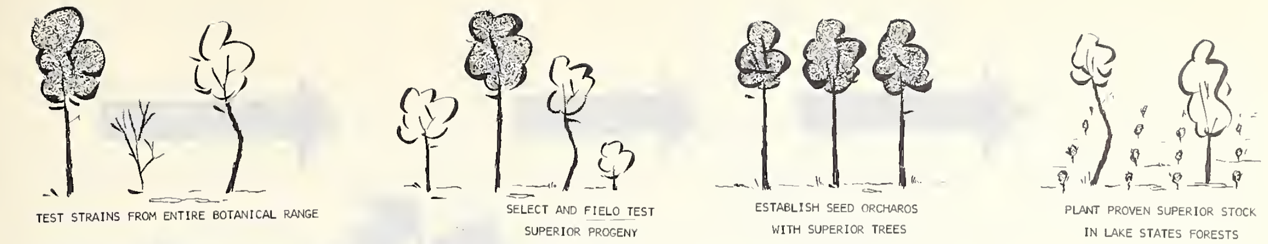
Scientists sometimes use radical treatments to obtain results. Here a research technician removes all living twigs from the top of a sugar maple. This is part of an investigation of the dormant buds that sometimes sprout on the main stem of a tree and develop into limbs that lower the quality of the wood. Several different treatments have been applied. In some instances the tops have been removed completely.



Species Selection is Important in Mixed Hardwoods

Many species of oak predominate in the mixed hardwood stands in central and southern portions of the Lake States. Some of the oaks produce good timber products, while others are scrub varieties. The forest manager in these areas must select the species that grow best and favor them in his land management practices, from the time that they germinate into seedlings until they are harvested.

The young trees must be protected from brush and grass competition until they are large enough to fend for themselves. Once a forest is established, the problem becomes one of species selection. Present research indicates that this must be done on an individual tree basis. Those trees that are undesirable must be killed. Certain herbicides can be used, although research scientists are still experimenting to determine which are best, what time of year they should be applied, and what concentrations are effective.



Experiment Station geneticists are trying to obtain superior trees from three major sources: comparisons of races and strains, selection in natural forests, and radiation-induced mutations. Once individuals are selected that *appear* to be superior, the procedure is similar for testing progeny from all sources. The best individuals among the progeny (those that inherit desirable characteristics) will be planted in seed orchards, where they will provide seedlings for future forests.

GENETIC IMPROVEMENT OF TREES

Mother Nature is a spendthrift — but she can afford to be wasteful because her time is unlimited. She can wait thousands of years for a species to eliminate its misfits in the battle for life. The genetic makeup of each individual largely determines how it will fare.

Man can't wait for Nature to do the job. He has to find shortcuts for developing superior strains. These shortcuts have turned disease-ridden wild wheats into the heavy-bearing hybrids that feed our Nation today. They can also be used to improve our forests.

But how can we compare grain to trees? Wheat is an annual crop, while trees must grow many years before they can bear seed. Several generations must be tested before superior trees can be singled out, and that would take more than 100 years. Land managers are asking for answers *now*.

No genetics problem can be solved immediately, but Lake States Station geneticists are looking for ways to reduce the waiting period. They are studying this and other puzzling genetics questions at the Institute of Forest Genetics, Rhinelander, Wis. They have at their disposal modern laboratory facilities, growth rooms, greenhouse and headhouse facilities, a radiation field, cold frames, an arboretum, and an experimental forest. These facilities were constructed to achieve one ultimate goal — the development of superior trees for northern forests.

How Can We Shorten The Time Between Generations?

Several theories might be used to make trees bear seed sooner. For instance, every growth characteristic, including that of producing seed, is triggered by hormones. If the right hormones can be isolated, they might be used to make pines bear seed profusely in 5 years or less. Also, certain species have rare individuals that bear seed early.


F-506154
Dr. Robert Buckman, research forester, inspects an aspen that is considered a superior tree. It is one of about 10 unusually good stems that all spring up from the same root system. A superior tree should put on better than average growth, exhibit good form, have small branches, and show resistance to the more common diseases.

Occasional jack pines will produce flowers when they are no more than 20 inches tall. Station geneticists are making use of this trait, selecting early-flowering individuals for future experiments.

Can We Stimulate Mutations?

Every change in the growth characteristics of a tree is caused by a change in its genetic makeup, called a mutation. Mutations occur only rarely in nature. Some improve the quality of the tree. Others are detrimental. If we could speed up this process of change, improved strains would show up more quickly.

Radiation is a tool that accelerates mutation. The Station's first radiation experiment was started about 15 years ago when jack pine seed was exposed to X-rays, then planted. Geneticists are now working with seed from the second generation. Pollen is even more susceptible to radiation-induced mutations. This is being studied, too. In another series of studies, geneticists are subjecting trees to varying degrees of radiation to determine what levels are most successful.

What About Superior Strains That Already Exist?

Certain strains of forest tree species are superior to others. To select those that are best the geneticists have collected seed from the entire botanical range of the species and planted it here. The strains that prove themselves best will be used to produce seed. This seed and cuttings and seed from local progeny-tested superior trees will be planted in "seed orchards." As the trees in the orchards mature, the poor ones will be removed. The rest will provide seedlings for more productive future forests.

Once We've Found a Superior Tree, How Can We Keep It?

No tree has really proven its superiority until it is mature and ready for harvest. By that time it will have shown tall and straight growth, resistance to disease, and other favorable characteristics. But the seed is carried high in the crown, where artificial pollination is difficult to handle. And before long it may decline and die. How can we preserve it?

Cuttings could be taken from the tree and grafted to young stems in the nursery, but this has drawbacks. Material from older trees often grows quite differently than that in the younger ones. Sometimes the stems grow much faster than the root stocks. When this happens, the graft may break and the cutting is lost.

Better yet, suppose we root cuttings from a superior tree? Some trees, such as willow, do this very readily. But others will do so only rarely. Here, again, hormones may help once they are better understood. This, too, is part of the genetics program.

What Else Is Being Done to Aid Genetic Science?

Fundamental research provides scientists with tools for future work. A U.S.D.A. Pioneering Research Unit has been established at the Institute for this purpose. This Unit is studying the physiology of wood formation, which goes right to the heart of the question, "How is wood made?" The results would provide important new building blocks for future genetics studies.

Engineering and Utilization

FOREST ENGINEERING

A relatively new area of research is that of forest engineering. It involves developing more efficient methods for harvesting and transporting wood, designing less costly systems for converting low quality stands to more productive ones, and designing new equipment for specialized forestry jobs. In today's highly competitive economy we must achieve more rapid progress in resolving forest engineering problems.

Now that our old-growth forests are gone, we are faced by a peculiar situation. Much of the forest cover in the Lake States consists of less valu-

F-506994
Field chipping of roundwood could reduce transportation costs substantially in the harvest of low-quality hardwoods. The Station's forest engineering staff and Michigan Technological University are cooperating to develop more information in this field. Pictured here are three Michigan Tech mechanical engineering students who are operating test machinery to determine the power requirements for portable chipping equipment.

able second-growth material and a scattering of old cull trees. Minerals can be mined at man's convenience, but a forest *must* be thinned and groomed to keep it productive. Timber products should be removed and efficient harvest and transportation systems can be developed to do the job. The Station's forest engineering staff has been assigned the task of developing such methods and systems.

One possibility that may reduce transportation costs is roundwood chipping at the harvest site. Under present methods low-value material is shipped to the mill as roundwood that will later be debarked and chipped for pulp and various composition products. If logs and bolts could be chipped at the harvest site, transportation costs might be reduced. Chips are easier to handle and the worthless bark would not be transported.

Power is an important unknown. Little is known about how much horsepower is required to chip the different types of wood. Previous attempts at field chipping indicate that light machinery could not generate enough power to do the job. Heavy machinery that could do the chipping turned out to be too cumbersome. Station engineers are studying this problem with the help of experimental machinery at the Michigan Technological University, Houghton, Mich.

The engineering staff is also undertaking a study of combinations of machinery that might be used to convert low-quality stands to more productive forest cover. Many thousands of acres in the Lake States are nonproductive today because of the high expense involved in stand conversion. Integration of machinery might lower the cost. Imagine the efficiency of a machine that could remove the trees, scrape away the brush, cultivate the site, and plant the seedlings, all in one operation! Such equipment should help to establish new forests on the huge areas that are now covered by brush and nonproductive trees.

GRADING AND PRODUCTS UTILIZATION

The Station's research program aims to cover the broad spectrum of forest-related activities, including the grading and processing of timber products. These two important activities are being investigated by our forest products utilization specialists.

Foresters Need Tree-Grading Guidelines

Trees must be sold on their stumps. The buyer gets everything — clear wood, knotty wood, leaves, bark, and rot. He takes what he can use and leaves the rest. If his purchasing price is based upon a good estimate of the value of the trees, he will make money. Otherwise, he will lose on the venture.

The logger's profit or loss is all too often based upon judgment. Many exterior features are indicators of tree quality — limbs, knots, holes, bumps, discolored bark, and swellings are a few. A forester who is familiar with certain combinations of these factors can make a rough estimate of the quality and quantity of sound wood in a tree. But more accurate methods are needed for grading, particularly when high value species are involved. The Station's scientists are examining in detail the quality of sugar maple logs. All features of the exterior and interior of each log are studied, recorded, and photographed to determine what combinations of exterior indicators give the best indications of interior quality.

F-504523
Research foresters James C. Ward and Richard M. Marden demonstrate the fieldwork they think will be used in the sugar maple grading system they are devising. Defect indicators will be recorded on punchcards. This information will later be fed into a computer, which will determine the grades of the logs.

The possible combinations of indicators are almost infinite. Those that are most important must be sorted out and put into a grading guide that can be used by the field forester. Such a huge undertaking was impossible before automatic data processing was available. Though the work is still very detailed and complicated, the study is well underway, and some of the less important indicators have been eliminated. When a grading system has been devised for sugar maple, studies will be started for other species.

New Ideas Help Farmers Use Wood

Not so very long ago wood was the basic material used in almost every construction job especially on the farm where the raw materials grew right on the property. Today modern technology has developed many substitutes that have taken much of the market. Station utilization specialists are working on new ideas that may again broaden rural wood use. Poles, for example, are a forest product that has many uses on the farm. If they are straight and durable they make fine supporting members for small buildings that house livestock and equipment. In many cases, poles have been replaced by other materials, simply because the poles were not straight enough. To solve this problem, the Station in cooperation with the University of Minnesota developed a jig that helps the pole producer straighten poles by sawing excess material off the crooked surfaces.

Other research has resulted in the development of small and inexpensive charcoal kilns. New work is underway to determine the effectiveness of preservative-treated jack pine posts and lumber in a number of different types of barnyard fencing and buildings.

COOPERATION IN RESEARCH

An effective forestry research program leans on a broad spectrum of knowledge in many fields. It is most productive where the environment encourages research. The Lake States Forest Experiment Station is fortunate to have the full cooperation of and a free information exchange with the universities, conservation departments, many private landowners, and forest industries. The Station's research program is carefully oriented to complement the efforts of others. The stimulation, cooperation, and support of these public and private organizations help all to work toward a common goal — the development of modern and efficient methods for establishing, managing, and protecting the region's forest resources.

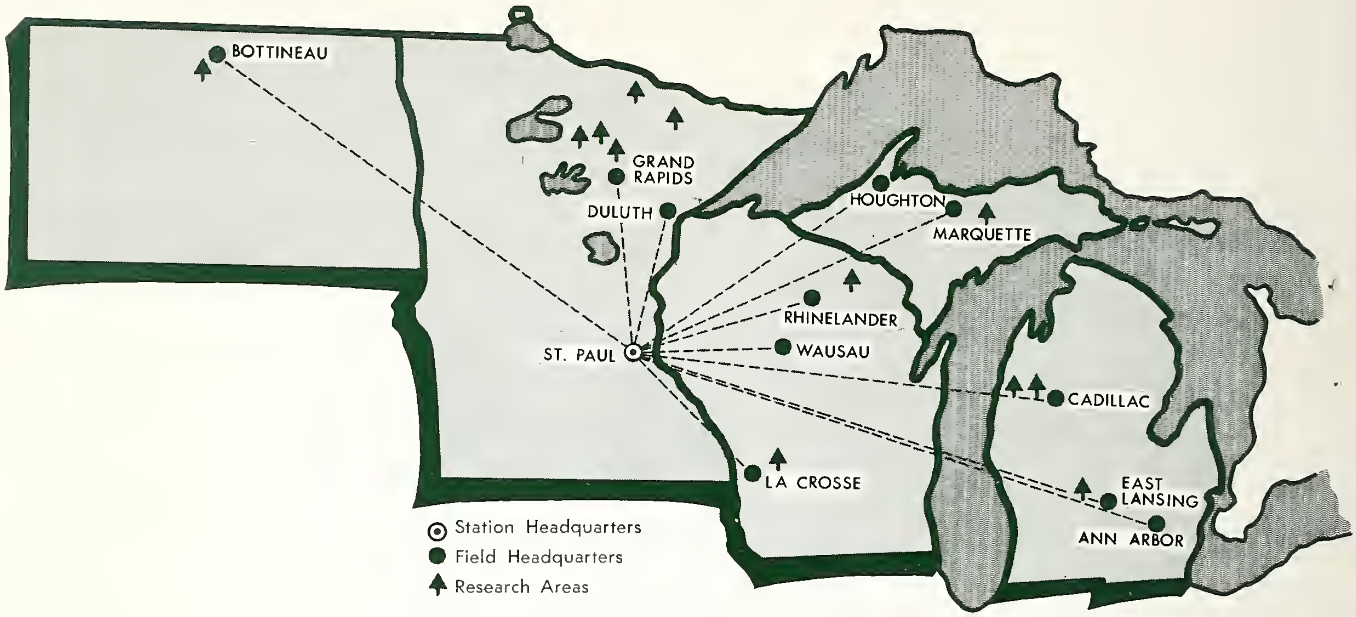
Northern Conifer Laboratory
Grand Rapids, Minnesota

Institute of Forest Genetics
Rhinelander, Wisconsin

Northern Hardwood Laboratory
Marquette, Michigan

Shelterbelt Laboratory
Bottineau, North Dakota

Lake States Station Territory



LOCATIONS OF OFFICES AND EXPERIMENTAL AREAS

The Lake States Forest Experiment Station is responsible for federal forestry research in the upper midwest. From its Headquarters Laboratory in St. Paul, Minn., the Station carries on a research program at 12 project locations and in 11 experimental forests and watersheds, as can be seen on the map above. A directory of these facilities is shown below.

Office Locations

ANN ARBOR, MICH., Univ. of Michigan Campus.

BOTTINEAU, N. DAK., Shelterbelt Laboratory, First St. and Brander.

CADILLAC, MICH., 119-½ S. Mitchell St.

DULUTH, MINN., Univ. of Minn. Campus at Duluth.

EAST LANSING, MICH., Michigan State Univ. Campus.

GRAND RAPIDS, MINN., Northern Conifer Laboratory, North Central School Campus.

HOUGHTON, MICH., Michigan Technological Univ.

LA CROSSE, WIS., 303 P.O. Bldg., P.O. Box 872.

MARQUETTE, MICH., Northern Hardwood Laboratory, P.O. Box 718.

RHINELANDER, WIS., Institute of Forest Genetics, Star Route 2.

ST. PAUL, MINN., Headquarters Laboratory, St. Paul Campus, Univ. of Minnesota.

WAUSAU, WIS., 802 First St.

Experimental Forests and Watersheds

ARGONNE EXPERIMENTAL FOREST, Hiles, Wis.

BIG FALLS EXPERIMENTAL FOREST, Big Falls, Minn.

COULEE EXPERIMENTAL WATERSHED, La Crosse, Wis.

CUTFOOT EXPERIMENTAL FOREST, Deer River, Minn.

DENBIGH EXPERIMENTAL FOREST, Denbigh, N. Dak.

KAWISHIWI EXPERIMENTAL FOREST, Ely, Minn.

LOWER PENINSULA EXPERIMENTAL FOREST:
Newaygo Unit, Newaygo, Mich.
Pine River Unit, Wellston, Mich.

MARCELL EXPERIMENTAL WATERSHED, Bigfork, Minn.

PIKE BAY EXPERIMENTAL FOREST, Cass Lake, Minn.

UDELL EXPERIMENTAL WATERSHED, Wellston, Mich.

UPPER PENINSULA EXPERIMENTAL FOREST, Dukes, Mich.